Agricultural Biotechnology And the Public

...That was the theme of four important regional information conferences sponsored by the U.S. Department of Agriculture, America's Land Grant Universities, State Agricultural Experiment Stations, and Cooperative Extension Services.

Southern Region • Raleigh, NC • February 22-24, 1988

Western Region • Reno, NV • March 28-30, 1988

Northeast Region • New Brunswick, NJ • April 18-20, 1988

North Central Region • Minneapolis, MN • May 16-18, 1988

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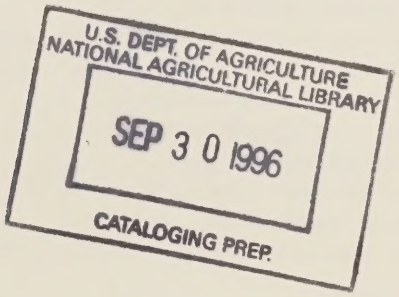

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THE PROMISE OF AGRICULTURAL BIOTECHNOLOGY

IS AGRICULTURAL BIOTECHNOLOGY the springboard for the second "Green Revolution"? It could be, says Max Lennon, president of Clemson University. He spoke at the Southern Region meeting on "Agricultural Biotechnology and the Public" in Raleigh, N.C.

The first "Green Revolution" packaged improved plant varieties with a set of field practices that were designed for farmers in Less Developed Nations. The results were "revolutionary." Food production spurted in those nations, relieving the pressure of population on food supplies.

OTHER SPEAKERS AT RALEIGH EMPHASIZED that ag biotechnology can circumvent natural, slow reproduction and selection for desirable traits in both plants and animals, and greatly speed up the improvement and versatility of plant and animal species.

AG BIOTECH MAY SPEED UP the adoption of resistance among plants to pests, diseases, frost, drought, and brackish water. Ag biotech may also produce new, more environmentally friendly treatments for pests, parasites, weeds, and diseases. Food processes, aided by biotech fermentation techniques, may improve food products and make them more varied, tasty, healthful, nutritious, and safe. That will benefit all humankind.

THE HISTORY OF HUMANKIND is our effort to modify our environment to better our lives, points out Dr. Fred Davison, University of Georgia. With the world's population headed for maybe 12-15 billion, the job will get tougher. I don't worry about food, Davison says. We'll find a way to eat. We might not like what we have to do, but if necessary we'll scratch out our food on small plots.

"I don't worry about energy," he says. "We'll find energy. What I worry about is what we are going to feed our factories," says Davison. His view: You can't produce wealth unless you produce a commodity. You can't produce a commodity without basic feedstocks. We live in an extractive society...40% of our oil use provides feedstocks for factories...and we are going to run out of oil. We must go to a renewable resource. Resources must come off the land. The answer: agricultural biotechnology. "Is there any other answer?" Davison wants to know.

BIOTECH TECHNOLOGIES will enable us "to shape the future in a fundamentally different way than ever before...a total change in the way we live and in the manner that we produce food, fuel, fiber, and chemicals," Davison says. We have the knowledge, he says, to re-program nature and ensure the continued progress of civilization...ban the specters of famine, pestilence...stabilize world conflict (brought on by seeking new resources)...engineer plants to resist disease, grow in salt water, thrive in drought, and yield new products in new climates...and provide increased forest cellulose to provide material for more efficient fermentation and chemical feedstocks to produce fuel, medicine, plastics, construction materials, and food.

"AMERICAN AGRICULTURE HAS SUCCESSFULLY come through a progression of hand power, horse power, tractor power, and chemical power. Now we are in biotechnolgy science power," observes Dr. James Halpin, director-at-large, Southern Regional Experiment Station Directors. Along the route, our agricultural productivity has increased steadily and has made us No. 1 in the world. Now, more than ever before, the public is involved in how we increase our agricultural effectiveness and the consequences. It is a partnership with the public that agriculture must learn to deal with openly and well if we are to stay No. 1., says Dr. Halpin.

IN THE ECONOMIC WORLD OF AGRICULTURE, the United States is in competition with other exporting countries. How are we going to go head to head with countries that have cheaper labor and cheaper land than in the U.S.? "The one bright light on the horizon is biotechnology...that catalyst for another "Green Revolution," Max Lennon answers. You measure the economic potential of ag biotech in billions of dollars, he says. "In the past, we have occasionally been faced with choosing between environmental purity and agricultural productivity. What makes biotechnology so exciting is that it can let us have both." Lennon adds.

AGRICULTURE'S URGENT CHALLENGE is to discover further "quantum leaps," such as the one we got from nitrogen fertilizer. Why the urgency? Because our entire food base is so narrow. Human life depends on a small handful of crops. Nearly all our human food around the globe comes from only 12 to 15 crop plants. About 90 percent of the calories eaten by the world's people come from only five cereal crops, three tuber crops, two sugar crops, and some legumes. That's right. Take the five cereal crops. They alone provide 70 percent of our food.

"These crops literally stand between mankind and starvation," says Dr. Gerald G. Still, director of the U.S. Department of Agriculture's Plant Gene Expression Center, Albany, Calif. Dr. Still spoke of the challenge and the emerging role of biotechnology at the Western Region Conference on Agricultural Biotechnology and the Public in Reno, Nev.

LOOK AT WHAT WE HAVE DONE IN AGRICULTURE: "Man has taken the germplasms from these few crops and has selected, manipulated, and kneaded them in an agronomic system that allows farmers to recover an ever-increasing percentage of the potential yield in each crop," Still explains. "Our crop culture and management system seeks to optimize water in relation to nitrogen and other nutrients, while constantly striving to reduce soil erosion and environmental pollution."

How does our scorecard look? We've been doing a pretty good job in some countries, thank you. Not so, in most of the world. Where do we go from here to ensure increased productivity and quality of the dozen or so crops basic to human survival? Dr. Still asks. Not only that. Where will we get the industrial feedstocks from which people fashion their goods--create their affluence, if you will--beyond simply eating to live?

THERE ARE THOSE WHO WONDER about agricultural biotechnology: Why be concerned about producing more food when we are now awash in surpluses, and farmers' prices are too low? Well, first, we are not awash in surpluses everywhere around the world. Further, we have a knowledge base for a much smaller world than we will have soon. And you don't just crank out knowledge on demand when you awaken to a screaming need. It has taken us 6,000 years or so to get agriculture where it is today. We don't have 6,000 years. We have maybe a dozen.

LISTEN TO THIS from Dr. Raymond W. Wright, Jr., animal physiologist from Washington State University: "Within the next 40 years food production must double to keep pace with the increase in human population. Much of the increase must come through more efficient distribution of nutrients in the plant into edible food....improved nutrient composition and availability to humans and animals...increased resistance to environmental and biological stresses... reduced loss from insects, parasites, and diseases...increased production using marginal cropland such as deserts and wetlands...improved animal health through reduction of disease and reproductive failure in animals...increases in biomass production...more efficient conversion to fuel and chemicals...and improved degradation of wastes in agriculture and food industries."

IT'S NOT JUST TOTAL FOOD OUTPUT...tons of production...that Wright talks about. He points out that we need to be concerned with how to get the food we need with the use of fewer resources and less stress on the environment.

DR. WRIGHT ILLUSTRATES ONE KIND OF PROGRESS he has in mind: It is now possible through cloning to reproduce like kinds of bacterial enzymes which break down cellulose, the main source of energy in animal feeds. Using these enzymes, we should be able to greatly increase efficiency of inexpensive feeds such as hay.

Embryo transfer provides the ability to produce 50 to 100 times more offspring from a single female than she can produce naturally. That can upgrade the genetic efficiency of the livestock population which can take advantage of the less expensive feeds.

We can take advantage of crops that cause less soil erosion...which take less fuel...which require fewer chemical pesticides...and which are more environmentally friendly.

WE ARE NOW AT THE POINT where we can build more quality, convenience, health safety, and gourmet appeal in foods through biotechnology, explains Dr. Ruxton H. Villet, leader of the U.S. Department of Agriculture National Product Utilization Program.

"Shifts in population age distribution, a tendency toward greater health and longevity, and the specific traits of various distinct age groups are motivating agribusiness toward new ways of making foods," says Dr. Villet.

Biotechnology will make a considerable impact in these areas, Dr. Villet promises.

"SCIENTIFIC KNOWLEDGE IS EXPLODING. Gains that would have taken years to achieve through selective breeding are now possible in a few days. Production costs can be lowered. Energy needs can be scaled back. Soil and water resources can be cleaned up. We can work much more harmoniously with the environment. Such are the promises of biotechnology," says Dean Stephen J. Kleinschuster, Cook College of Agriculture, Rutgers University. On that note he opened the Northeast Region Conference on Agricultural Biotechnology and the Public in New Brunswick, N.J.

WE ARE MOVING FAST IN BASIC BIOTECHNOLOGY. Consider this: Two years ago, the Food and Drug Administration surveyed 100 biotechnologists in academia, industry, and government, and asked what uses of biotechnology they anticipated and when these uses would become technically feasible. The majority thought the uses they anticipated would be technically feasible in 5 years, reports Dr. Thomas J. Montville of the Department of Food Science at the New Jersey Agricultural Experiment Station.

But moving from "technically feasible" to practical application can be a long step requiring hard work and scientific brilliance. Are we ready to move ahead rapidly in this revolution, stay on top, and be competitive in a world of intense scientific competition?

THE FIRST HURDLE is our national research capability, says Dr. Al Young, director, Office of Agricultural Biotechnology, U.S. Department of Agriculture. He reminds us that the President's Commission on Industrial Competitiveness reported in 1985 that (1) our ability to compete in world markets is eroding; and (2) growth in U.S. productivity lags far behind our foreign competitors.

WHAT'S WRONG HERE? For one thing, our development and use of technology is lagging. Regulatory restraints are inhibiting innovation and commercialization, the Commission on Competitiveness says.

Military functions are taking 68 percent of our Federal research and development funds. Federal agricultural research gets 1.5 percent. Granted, the States have a responsibility for agricultural research, while military research and development is solely a Federal responsibility.

THE SUCCESS OR FAILURE OF OUR SCHOOLS, colleges, and universities will either secure or forfeit America's place in the world, the Competiveness Commission says. In 1986 the White House Science Panel on the Health of U.S. Colleges and Universities concluded that educational facilities and instrumentation critically need updating. Federal obligations for R&D facilities in universities and colleges have dropped from $200 million in 1967 to about $25 million annually since 1974.

UNIVERSITY AND COLLEGE DEGREES in science and engineering, both undergraduate and graduate, have fallen off as a percent of total degrees granted since the early 1970's. The proportion of our 22-year-olds with projected degrees in science and engineering are falling. However, the doctoral degrees awarded to foreign students as a percent of all degrees granted by U.S. universities have moved up rapidly since 1960. In short, we have a national problem in producing new technology and in transferring technology.

"To change this will require a new vision and a new resolve, including closer industry, university, and government cooperation," concludes Dr. Young. Our competitiveness and our progress in this promising new world of biotechology hang in the balance.

BUT THE PROSPECTS ARE ENORMOUS, reminds Dr. Patrick Jordan, administrator of the Cooperative State Research Service of the U.S. Department of Agriculture. "We are seeing the dawn of a new era; a technical revolution that could rival the impact of the industrial revolution," Dr. Jordan states. "The micro-manipulation of genetic information directed to a targeted effect is a dream come true," he says.

THE ENORMITY OF THE POSSIBILITIES FOR GOOD charges us to do our best in a cooperative partnership of private industry, citizens, and government, Dr. Jordan advises. Meantime, we continue to debate whether regulations are too strict or too loose. Some question the basic tenets of biotechnology.

"We must lay it all out on the table and allow citizens to criticize and put in reasonable checks and balances on the way to the successes. On this threshold of pivotal change in agriculture and the way of life around the world, knowledge is critical to all of us. If we will communicate well with the public and listen well, and adjust accordingly, we can meet the rendezvous with destiny that the scientific community has in solving major problems of mankind," Dr. Jordan sums up.

AS WE ENTER THE LAST DECADE of this century, agriculture's job is tougher. We are challenged to provide the highest quality of food and fiber at lower costs. From abroad comes the challenge of competition for international markets. Here at home we are challenged to protect plant and animal health...while providing maximum protection for human health and the environment. How to do that?

The answer lies in research...development...adaptation...and education, says USDA Assistant Secretary for Marketing and Inspection Services Kenneth A. Gilles. He opened the 4th regional conference on "Agricultural Biotechnology and the Public," in Minneapolis, Minn.

ASSISTANT SECRETARY GILLES POINTS TO the fortuitous development of one of the "greatest scientific breakthroughs of our time--the discovery of the structure and importance of DNA," the makeup of that remarkable double helix string of life that carries the genetic messengers with instructions for all living cells. Now, through biotechnology methods, we can identify good DNA genetic messages coming from that magic string in one species...pluck out those genetic messengers...and shift them to another species.

It couldn't happen naturally. Different species usually are sexually incompatible and don't breed. Borrowing good traits speeds up the ability to improve our quality of life. "I believe we all share the confidence that biotechnology offers the creative potential to solve some of the more difficult problems facing the agricultural community today," says Dr. Gilles.

IN THIS NEW ERA don't overlook the oceans. Land plants have given us our food and fiber and several important medicinals. But about three-fourths of all life forms are in the oceans, relatively unexplored. The sea is an exotic mixture. There are thousands of kinds of ocean plants. Sea creatures make some of the most powerful chemicals known. The sea can be a rich area to survey, using the rapidly expanding techniques of biotechnology.

SOME BIOTECHNOLOGY FUNDAMENTALS

SCIENTISTS MUST "DEMYSTIFY" biotechnology, dispel fears and misconceptions, and provide information necessary for the public to make informed judgments, Dr. Susan K. Harlander, University of Minnesota professor, told the Raleigh conference. Good idea, because your head can swim when scientists talk about the new tools that make up biotechnology: Things such as genetic engineering, tissue cultures, protein engineering, fermentation technology, biosensor applications, DNA probes, monoclonal antibody assays, hybridoma, constructing gene constructs, introducing genes into the genome, the role and universality of restriction enzymes, cloning vectors, and expression systems.

BUT PEOPLE WOULD ALSO GET GLASSY EYED hearing engineers talk in their jargon about what goes on under the hood of an automobile--or if people heard aeronautical engineers discuss jet propulsion and the theory of flight. John and Jane Public simply want to know--will it get me there safely and at a reasonable cost in some comfort?

That's what they wonder about agricultural biotechnology. Is it safe, or is it likely to release some genie from the bottle that you can't stuff back in--and will it do me some good? Scientists owe them answers--and assurance--in easy five- or six-letter words.

TAKE HEART. WE'RE BLESSED, OR FORTUNATE. "We stand on the verge of a new era...on the edge of a 'technological revolution'...ranging from plant and animal agriculture to human medicine...made possible through the application of physical and biological sciences to manipulate living things through their informational molecules," says Dr. Gerald G. Still, director of USDA's Plant Gene Expression Laboratory, Albany, Calif.

Imagine that. Minute informational molecules present in all life, telling each structure what to do and when, and when to stop doing it. It's a turbulent, complex, vibrant, fascinating world that you can't see with the naked eye. We're just beginning to understand it. Barely so. We're only at the doorway. What we're beginning to understand is "how" nature works. That takes us no closer to "why." Science has never told us that.

MESSENGER MOLECULES MAKE US--and all the living things around us--what we and they are. It's a world of "nucleic acids, proteins, carbohydrates, and lipids all translating information to various levels of the biological system," says Dr. Still.

Take insects: Karomone and pheromone informational lipids regulate their behavior.

Take plants: They respond to cues through informational messenger molecules from nucleic acids through yet-to-be-determined micro and macro molecules.

Take mammals: Their lives are carefully orchestrated throughout "the progress of life through interactions of proteins that provide discrete information and function," Dr. Still explains.

WHAT WILL BE DIFFERENT ABOUT THE agricultural revolution ahead? It's a revolution that may dwarf the mechanical, genetic, and chemical revolutions in agriculture that preceded it, in the opinion of Dr. Ken Farrell, vice president for agriculture and natural resources at the University of California. We are about to use these "messenger molecules" to manage and manipulate field crops and livestock like nothing you've ever seen before, or even imagined. Call it bioregulation, if you will. Scientists would say it's using a "specific molecule architecture to elicit a specific biological response."

YOU COULD SAY THAT it's pushing the right genetic button, or bead, at the right time to get the exact response we want from plants and animals. We've done the best we could over the last 6,000 years or so of plant and animal breeding and selection for desirable traits. We have moved a lot of genetic beads around--and hit the right combination now and then to get a favorable response--but we've often gotten messages we didn't want, along with those we did. It has been partially effective, yes. Some would say we've made a lot of progress. Well, we have. But what we've done is crude and frustratingly slow compared with the potential that lies ahead.

Our problem was we couldn't see the genetic beads. We calculated they were spotted along a twisted string of DNA, that incredible string of life that gives all living things their characteristics. We knew that each offspring got beads equally from the male and female parents...but we didn't know which bead did what or where it was...and most limiting and frustrating of all, we couldn't move the beads from one species to another. If the species didn't mate, say corn with wheat, you couldn't transfer any beads and their messages. Now we're going to do that...with biotechnology...we're doing it...to get the specific response we want.

THEN THERE ARE THE BAD GUYS with harmful messages. Some viruses, say. They enter a living cell and their molecule messenger tells the cell to duplicate the virus. The cell stamps out new viruses like a Xerox machine run wild. Soon the cells are singing the viruses' song...a doleful funeral dirge...because the virus is making the host sick and may kill it off unless the host's defenses realize what's up and get busy bashing the viruses. Well, now we're beginning to put new messages in some of these bad guys. The virus invades a cell but he sings "Oh, what a beautiful morning" just like we want him to. No funeral dirge. Still, the cell realizes he's a foreigner singing off key and calls out the virus bashing squad. Voila, the host builds up an immunity to future attacks by genuine bad guys with bad messages. Biotechnology has used a molecule message to get a specific response.

WRITE DOWN, UNDERSCORE, AND CAPITALIZE the word SPECIFIC. Biotechnology is not a wild undisciplined, who-knows-what-in-the-world-will-happen-next kind of bioregulation. It's specific: using specific molecules to carry a message that gets a specific response.

It's not as if a messenger molecule rushes in and shouts "Fire!" and everything in the body cells dashes every which way in a frenzy, creating some unknown...or monstrous results. Instead, the messenger molecule says, "I'm going to take you by the hand and lead you carefully down this flight of stairs and through the hall out the South door and into the parking lot at 11:58 a.m., because at 12:00 noon this place is going to burn--and you can count on that."

You might say that what we're going to do in biotechnology is to put a human-directed chauffeur on these messenger molecules who will help to drive them to the right place at the right time to deliver the right message.

What we're doing now in biotechnology is learning all we can about "specific messenger molecules" and the messages they transmit and exactly what response they get. "The future of agriculture resides in our ability to optimize the use of these informational molecules," says Dr. Still.

WHAT COULD WE DO, FOR INSTANCE? Well this: Control the timing and termination of the vegetative phase of plant growth, as well as initiating reproduction. Manage the translocation of nutrients in concert with weather and flowering. Postpone the senescence of old age by maintaining vegetative and reproductive metabolism for longer periods. Control seed dormancy. Regulate metabolism after harvest to preserve the product better or maintain quality longer.

Develop plants that make better use of water...even plants that will grow in brackish water. Make plants resistant to insects. Make vaccines that ward off diseases. Make safe pesticides that attack only one specific pest. Strip out the bad messages in genetic beads. Develop new products. Make more varied, healthful foods. And more.

BUT KEEP YOUR SHIRT ON. One of biotechnology's problems is that while the use of informational molecules has enormous potential...expectations also have been enormous...while our experience so far is small...timeliness has not been realistic. "Our dreams of using informational molecules to orchestrate the biological process are valid. However, the investment of human and capital resources to understand the intricacies of these codes--the interrelationships between the words, sentences, and paragraphs of the messages--have yet to be worked out," says Dr. Still.

GENETIC ENGINEERING HAS DEVELOPED RAPIDLY just in the last 2 years. "Today, we can find any gene whose action we can recognize and isolate, engineer, and reintroduce it into the organism from which it came, or into an increasing number of other, unrelated organisms," says Dr. Hans J. Bohnert, plant biochemist at the University of Arizona. Not only is it possible to transfer salt grass genes into barley, it is also possible to take barley genes from lines that have been selected over the years for brewing and baking qualities and transfer them to salt grass.

"There are more possibilities," says Dr. Bohnert. "We are not restricted by sexual compatibility as classical breeding is. In order to combine superior qualities of several crops, it is possible by using this approach to obtain specific proteins from beans as a component in wheat or salt grass or barley."

In other words, we can transfer gene beads and their molecule messages from one crop to another, even though the plants do not mate with each other. We do it in the laboratory. No ogres, there. Just a transfer of good messages.

DOES USING THESE TOOLS OF BIOTECHNOLOGY replace classical breeding? "No. It enhances classical breeding," says Dr. Bohnert. What about the argument that if a certain gene was meant to be in barley it would already be there? "That is false," answers Bohnert. Superior genes in barley for baking bread are of no value to the plant, he explains. Only for us. We concentrated those genes in barley strains through classical breeding, starting about 5,000 B.C.

REMEMBER THE "BAD-GUY" DISEASE-CAUSING ORGANISMS? Rapid tests for three diseases caused by parasites have come out of biotechnology work done by Dr. Charles Sterling of the University of Arizona. Take Cryptosporidium (Crypto), a diarrhea-causing protozoan transmitted in polluted water throughout the world. You can't kill the organism through conventional water treatments, even those used in sophisticated city water supply systems. Crypto frequently attacks small children and is known to hit a fourth of AIDS victims. The flue-like symptoms last 2 to 21 days in healthy adults, but Crypto is a serious threat to very young or malnourished children.

Dr. Sterling, using biotechnology processes, developed monoclonal antibodies that recognize tell-tale antigens from Crypto. He bound these antibodies with a chemical that produces a fluorescent glow. The resulting reagent reacts with a smear sample within 20 minutes, showing whether the person is infected with Crypto. "Under a flouroscopic microscope a positive smear looks like small headlights glaring up at you; you can't mistake it," says Sterling. The diagnostic test he developed through biotechnology techniques has been licensed and is now on the market.

CRYPTO IS A BAD ACTOR. It causes typical calf scours diarrhea in calves and costs the U.S. cattle industry $200 million in losses annually. It also causes diarrhea in sheep, pigs, pet store parrots, and in rodents. Antibiotics that cure other parasite-caused diseases won't help with Crypto. But being able to identify the parasite early enables doctors to avoid useless drugs, which may worsen the disease, and concentrate on keeping patients from dehydrating.

Another parasite that reacts to Dr. Sterling's tests from his biotechnology work is Giardia, which infects as many as 15 percent of the U.S. population, but often goes undiagnosed and untreated, even in critically ill patients.

Another parasite, Bovine cysticercosis, which is prevalent in Third World countries, needs accurate diagnosis. Eating meat infected with the parasite causes tapeworm. With the test card developed by Dr. Sterling, two small reagent bottles, and a single drop of blood, the infected cattle can be culled before slaughter. Another success for biotechnology. No pie-in-the-sky there.

ONCE AGAIN, WELCOME TO THE BIG, NEW never-to-be-the-same world of agriculture, about to be transformed by biotechnology. The promise: Faster speed. New crops, superior animals, and more diversified food and fiber. Better capability to deal with insects, diseases, weeds, drought, cold, and environmental stresses. All because we are rapidly developing new tools and discovering new knowledge to deal with the fascinating microscopic world of genes, hormones, enzymes, and the micro messages that govern all plants and animals.

IMAGINE THIS, IF YOU WILL: Every cell in your body has the instruction manual in its nucleus to build and operate every part of your body. The instructions are written out in four letters, A, T, G, and C. All words are three letters long, each a code for making an amino acid, explains Dr. H. Graham Purchase, special scientific advisor of the USDA Agricultural Research Service. There are many chapters in the instruction manual. The messages are carried on a double strand with the T and the A always opposite each other, and the G and the C opposite each other. That's the code of life, whether it's in humans, ants, or bacteria. The messages along the strand might look like this, says Dr. Purchase:

GGATCCGTAAGT
CCTAGGCATTCA

HOWEVER, EACH CELL NUCLEUS is instructed through a genetic command to read and carry out only the chapter in the manual that relates to the product or function of that particular cell in which it resides. That's what gives genetic engineering its predictability, fascination, and power. "The ability to 'snip out' chapters from the manual and 'splice in' new chapters...even from an instruction manual for another species...is one of the great breakthroughs of this century," Dr. Purchase states.

SCIENTISTS USE A RESTRICTION ENZYME to snip a genetic message from the double strand of the chromosome. The enzyme cuts in a zig-zag fashion like this:

GGA TCCGTA (remove right side & insert new message)
CCTAGG CAT (remove right side & insert new message)

The strand on the left has what Dr. Purchase calls a "sticky end" that will cause it to fit into a new coded message with the same configuration inserted on the right. Those new messages can be inserted through the cell wall with a

micro syringe, can be shot into the cell, or can be placed there electrically. That's the essence of genetic engineering and recombinant DNA, rDNA, (inserting new genetic messages from another chromosome and "recombining gene messages").

"GENETIC ENGINEERING IS one of four major revolutions of this century, on a par with unlocking the atom, escaping earth's gravity, and the computer revolution," a panel of experts from the Department of State has declared. The impact of biotechnology will surpass the other three, Dr. Purchase predicts.

But we're just beginning to move into this revolution. True, we've known some of the techniques for a long, long while. Fermentation is as old as bread baking and brewing beer. We've also been doing plant breeding for 6,000 years or so; ages before Mendel, the Austrian monk, the father of genetics, gave us a better clue in the 1800's as to how it works. However, we also knew about jet propulsion long before we harnessed it to escape the earth's gravity.

"WE'RE JUST NOW LEARNING how to edit a page of genetic instructions," says Dr. Purchase. "Our current techniques for reading the genetic code are slow and very expensive," he says. We still use trial and error in shifting chapters, pages, paragraphs, and words. Occasionally it works. Sometimes it doesn't, and we don't yet know why.

WE CAN, FOR EXAMPLE, remove from chickens the DNA gene instructions for chicken growth hormone (chicken somatatropin, cST) and insert the instructions into a bacterium. The Escherichia coli bacterium reads the instructions and produces cST, explains Purchase. When we inject the recombinant cST into chickens, it increases growth. We can do the same with bST in cattle and with pST in hogs.

The recombinant bovine hormone, bST, boosts milk production in dairy cattle; pST increases feed efficiency in hogs. As yet, cST seems to have little effect on chickens, and we don't know why. So there are many, many things to learn about this new biotechnology world that is just opening up to us.

For example: Dr. Purchase estimates that it would take 10 to 20 years and $10 to $20 billion to read and decipher all the gene messages in the human geno. "We simply don't understand the purpose of many genes," he says.

SHIFTING GENES FROM ONE ORGANISM TO ANOTHER opens a new era for biology. It has far-reaching implications for agriculture...human health...industrial processes ...and for society, says C. Eugene Allen, acting vice president for Agriculture, Forestry, and Home Economics at the University of Minnesota, and acting director of the Minnesota Experiment Station. Biotechnology is expanding our understanding of molecular, cellular, and whole organism processes, Dr. Allen says. Thus we understand better such things as how plants or animals grow...develop... flower...lactate...fight diseases...develop resistance or susceptibility... partition nutrients into muscle, milk, or fat...develop food flavors...or carry out other aspects of life that are important to agriculture and society.

REGENERATING WHOLE PLANTS FROM CELLS through tissue culture makes it possible to manipulate and test millions of cells in a petri dish rather than handling millions of plants in the field. "This is potentially far more efficient," observes Prof. Ronald L. Phillips, University of Minnesota. "The cell becomes the unit of selection instead of the whole plant."

But Dr. Phillips points out that biotech scientists are learning something else from tissue culture. Originally, scientists thought that this cloning would give them plants that were all identical to the plant from which the cells came. Not so. "Genetic changes occur as cells reproduce themselves in this artificial environment," he says. "This culture process allows us to create new variability in crop plants for such traits as disease resistance, nutritional quality, herbicide resistance, maturity, and yield."

HOW BIOTECHNOLOGY IS CHANGING PLANTS

FOR SLOW NATURAL IMPROVEMENT, take forest trees--of which pines are a major renewable resource. Traditional tree breeding improves seed lines, but it's slow, slow, slow. Establishing seed orchards and seed production for better yielding trees with higher disease resistance "may require 5 to 15 years and another 4 to 12 years for progeny testing to find which parent trees consistently produce improved offspring," observes Dr. Ralph Mott, North Carolina State University.

"Emerging biotechnology methods provide the first hope of surmounting these natural obstacles," says Dr. Mott. "Forest trees have now risen from last place in the plant biotechnology arena to contend for first place," observes Dr. Mott, who did pioneer work in tissue culture cloning of superior trees. That cloning process can knock 5 to 15 years off the normal pace for improving trees.

Mott and his associates have cloned thousands of trees that are in field tests across the Southeast. Still needed: A less costly way to clone.

Another breakthrough coming: testing for tree rust resistance in test tubes rather than waiting for observations in standing forests. Again, it's a way to knock years off the development of superior trees.

"WE CAN ELIMINATE VIRTUALLY ANY DISEASE from any plant and mass propagate that plant by using tissue culture," states Dr. Robert Hartman, president of Hartman Plants. His firm uses the technique to produce...and export...large quantities of plants, such as paladium.

Dr. Freddi Hammerschlag of the Agricultural Research Service, U.S. Department of Agriculture, is using tissue culture extensively to get resistance to bacterial leaf spot in self-rooting peach trees. Still to solve: the economics of tissue culture for farm plants.

GET USED TO HEARING ABOUT BIOHERBICIDES. People will be talking more and more about them. And why not? It's fascinating, really. Dr. George Templeton of the University of Arkansas tells about a little fungus that likes northern jointvetch, a weed in rice and soybean fields. Ordinarily, northern jointvetch shrugs off the fungus, which produces only inconspicuous lesions on stems and pods.

Arkansas scientists took the fungus into the lab and found that when they applied it on jointvetch in concentrated suspensions, it was lethal. They tried it on crops. No effect. They tested it on animals. No effect. EPA approved large-scale field trials. It passed, attacking only jointvetch. Aerial applications stood up. "Grower experience with the product has been excellent, and it has made a profit for the commercial producer," Dr. Templeton says.

There are more of these on the way, says Templeton: Mycogen Corporation expects to commercialize a native fungus for control of sicklepod in soybeans and peanuts in the Southeast. Philom Bios Corporation in Saskatoon, Saskatchewan, expects to bring along a fungus to control roundleaf mallow in wheat and lentils. In Australia, the New South Wales Department of Agriculture seeks a license to bring out a native fungus to control spiny cocklebur. Fourteen other countries are doing research on native fungi for development of bioherbicides.

Universities and industry working together can produce a synergy vital for the U.S. to maintain leadership in agriculture, says David Drahos, Monsanto.

THE MYCOGEN COMPANY HAS DEVELOPED A CLEVER bioinsecticide product. The company genetically engineered bacteria to produce a toxin from another kind of bacteria. The toxin was fatal to insects. The company then killed off the engineered bacteria with a process that hardened the wall around the bacteria, with the toxin inside. Since the bacteria were dead, they couldn't grow or harm

the environment. Next step: spray the dead, encapsuled bacteria on crop leaves. When insects eat the sprayed leaves, the capsule dissolves and the toxin does its lethal work in the insect's digestive system. This is an advantage over putting live genetically engineered bacteria into the environment, for they must hurdle a longer, slower regulatory process, says Dr. Jerry Caulder, president of Mycogen.

LET'S SAY THAT THROUGH BIOTECHNOLOGY WE DO GREATLY INCREASE the ability of plants to produce food and energy. Those plants will still require water... lots of water...a vital ingredient which often limits production and causes plant stress. Adequate water is a growing barrier to higher yields all across this country and around the world. Water will be a problem for the new biotechnology era we are entering. "But a water supply for crop production has been a worldwide agricultural concern throughout history," reminds Dr. Ilga Winicov, associate professor of Microbiology and Biochemistry at the University of Nevada.

Not only do we have a problem getting enough water for crop production, but using irrigation to bring more water to fields leads to salinity buildup in farm soils, making them less hospitable for crop production, Dr. Winicov reminds us.

Some plants have developed the ability in nature to survive and produce under dry and saline conditions. Can we capitalize on that, through biotechnology, and successfully transmit the salt tolerance of marsh grasses into a commercial hay crop, such as alfalfa?

Professor Winicov is helping to unlock that door through the use of genetic engineering, molecular biology, and plant tissue culture. Her laboratory is "identifying genes which are differentially expressed in salt-tolerant alfalfa cells."

SUCCESS IN DEALING WITH SALTY CONDITIONS could pay big dividends. "Half of the world's 400 million acres of irrigated land suffer from salt or drought problems --and the other half is getting saltier," observes Dr. Hans J. Bohnert, plant biochemist at the University of Arizona. Ten million acres of cropland are irrigated in the American West alone. More of this acreage is dropping out of economical production each year because of the buildup of salt in the soil from constant irrigation.

"PLANT BREEDERS HAVE COME TO A DEADLOCK in breeding for salt and drought tolerance because it is a complex, multigene trait involving at least 10 genes. Only the simultaneous improvement of all the genes would produce success," Bohnert explains.

"Only genetic engineering can provide a definitive approach for transferring multiple genes in a reasonable amount of time, with reasonable cost," Dr. Bohnert says. He is working at transferring the "extraordinary salt tolerance of salt grass" into barley. He describes the potential payoff:

Any isolated gene that can improve one crop is available forever. "Its equivalent gene does not have to be found in every crop plant. Rather, we can take a gene from any plant to improve another crop," Dr. Bohnert says.

A FEW YEARS AGO if you had suggested, "Why don't you use the bacterium from crown-gall to improve black cherry trees in New York State to upgrade high-value veneer?" people might have raised their eyebrows or carted you off. Now, using biotechnology techniques, scientists at the Suny College of Environmental Science and Forestry are using crown-gall to insert genetic messages into young black cherry shoots to produce better trees with a value perhaps 100 times greater than run-of-the-mill black cherry stock, Dr. S. W. Tanenbaum of Suny reported at the Rutgers conference.

SOMETHING ELSE GOING ON AT SUNY: Scientists are investigating the biochemistry of microbial oxidation enzymes which can attack lignin-related structural compounds. They plan to improve enzyme-secreting strains genetically. The aim: Get natural catalysts they can harness to "ameliorate a number of forest-based industrial pollution situations." In the vernacular, harness bugs to reduce environmental pollution.

SCIENTISTS AT SUNY have discovered that an antibiotic-type substance developed by Merck, Sharpe & Dome knocks gypsy moths for a loop. The gypsy moths are "exquisitively sensitive" to the antibiotic. A tiny bit kills them. Gypsy moths are voracious insects that denude trees in the Northeast. Despite major efforts to contain gypsy moths, they keep moving farther south and west. They are now chewing their way methodically into and across Virginia.

SUNY SCIENTISTS are now checking to see if the antibiotic will have the same effect on other insects and nematodes. As far as is known, the antibiotic is relatively nontoxic for vertebrate animals. Again, using biotechnology techniques, scientists are working to design insecticides that are deadly to specific insects but friendly to the environment.

In other work, Suny scientists are converting unwanted byproducts of the wood processing industry into commercially useful starch and cellulose.

OVERALL, CLONING IS EASIER IN PLANTS than in animals. Scientists can produce complete plants from leaf cells taken from adult plants. This is not to suggest that biotechnology advancements in plants are a cakewalk. Dr. Robert J. Griesbach, Agricultural Research Service, U.S. Department of Agriculture, points out that "the methods for transferring drought tolerance in plants may or may not be successful in transferring herbicide resistance."

He explains that each characteristic--drought tolerance, yield, and so on--is influenced, not by one gene, but by a number of genes. Not only that, "these genes must be active in the correct tissue at the correct time," he says.

For example, "it would serve no purpose to transfer new, improved protein characteristics to corn plants if these new characteristics were expressed only in the leaves and not in the seed," Dr. Griesbach points out.

Biotechnology is not easy, but we're making progress every day.

BIOTECHNOLOGY BRINGS THE PROMISE--and the ability--to compress time. Take penicillin. When scientists first started making penicillin with a fermentation process, they harvested about two units of penicillin per milliliter. After 40 years of refining techniques, they achieved a harvest of 50,000 units per milliliter. In one quick jump we can double the penicillin harvest through biotechnology processes, Dr. Tanenbaum points out.

LOOK AT ANOTHER EXAMPLE OF COMPRESSING TIME: If you are a plant breeder using the time-tested classical breeding techniques, you select the best plants you can find for certain characteristics. Let's say you select carrots for color, sweetness, size, and texture. You cross these better carrots with each other. You save seed from those that are particularly strong in the characteristics you are selecting for, plant another generation, select the best again for seed, and cross these best plants. Eventually you can concentrate the genes with the "good messages" to upgrade the line. That's takes a long time working with several plant generations.

ONCE IN A WHILE in classical breeding, or in the wild, a mutation springs up that somehow contains an unusual combination of gene messages that makes that plant especially different from the others. It may be much sweeter, a different color, or whatever. The mutation leapfrogs ahead of the other plants of its kind. Some of our long-time standard varieties have developed just that way, naturally. Someone had the good judgment to use the better performing plants for seed or for grafting, as in fruit.

ANOTHER WELL-KNOWN BREEDING TECHNIQUE IS HYBRIDIZING. You can create hybrids by pollinating plants back to themselves and planting the seed. This inbreeding concentrates the undesirable characteristics. There's more chance through inbreeding that recessive "bad" genes will pair up and express themselves, which you can then observe in the plant.

You save seed from the better quality plants. You inbreed still further and discard still more plants with undesirable characteristics. Usually, inbred plants lose vigor. But when you cross these inbred lines you get a boost in vigor and better quality than you started with. You have created a hybrid.

"THROUGH THE USE OF BIOTECHNOLOGY, we can now make hybrids from plants that can't be crossed using pollen. Tomatoes with potatoes, for instance," USDA's Dr. Griesbach explains. "Further, we can produce drought resistance or other qualities that would take 15 years in classical breeding, and do it in 6 months to a year," says Dr. Griesbach.

"Beyond that, instead of producing a million plants, hoping for a random expression for a characteristic in nature, we can find the characteristic in another species and transfer that single characteristic from the other species," Dr. Griesbach explains.

SPEED, BUT WE AREN'T ALONE. Listen to Dr. Barbara Zilinskas, professor of plant biochemistry, Cook College of Agriculture, Rutgers University: "By tranferring a single gene of great specificity, we can avoid 15 generations of classical breeding. Further, we can concentrate gene messages that tell a leaf to produce materials that are toxic to insects, but are not produced in the edible fruit of the plant," she says.

We aren't the only ones doing this, Dr. Zilinskas explains. Gene splicing and transferring genes from one species to another "is having a great effect around the world and is showing up in scientific journals in other nations."

NOW FOLLOW THE BIOTECHNOLOGY ROUTE taken by the DNAP Company of Cinnaminson, N.J. Dr. Robert Morrison of that company points out that DNAP is taking advantage of the principle that each cell in a plant has the instruction manual to make a complete plant. DNAP scientists grind up leaves of carrots into tiny bits. Scientists put each leaf bit into a sterile growth medium in a small test-tube-like container. The tiny bit of plant life begins to construct a new plant with roots, stems, leaves--the complete thing. DNAP sets out these plants in large numbers to grow.

Something else happens, says Dr. Morrison. Under these conditions new plants from the leaf cells are inclined to produce many more mutations. They leapfrog ahead with stronger characteristics that you want--and sometimes leap backward in characteristics you don't want. Again, you select the best and then use tissue culture to produce identical plants of the upgraded kind.

DNAP is upgrading carrots, celery, and sweet peppers with the aim of producing better, more healthful vegetable snacks for diet-conscious consumers. On the list of other possibilities: popcorn and tomatoes. DNAP has also developed a test kit for diagnosing brown patch disease on golf courses.

DOWN THE ROAD, WAITING FOR A BROADER BASE of fundamental knowledge, is the challenge to develop a plant that will make its own nitrogen fertilizer, says Dr. Zilinskas. "Needed now more than ever before," she says, "is a concerted research effort in the supporting fields of biochemistry, physiology, and genetics to indentify the genes encoding desirable traits and to learn how their expression is regulated."

BIOTECHNOLOGY IS GIVING US ANSWERS to problems that have plagued us for centuries. Take the disastrous Irish potato famine of more than 140 years ago. The cause was "late blight," a disease that devastated potatoes...the Irish food staple...causing famine, and sending many Irish citizens fleeing to the U.S.

Late blight still plagues potatoes. Our U.S. potato crops are not yet resistant to this fungal disease. Potato farmers must spray...as often as once a week...at a cost of $5 to $10 an acre, points out Dr. John P. Helgeson of USDA's Agricultural Research Service, stationed at the University of Wisconsin.

But there are wild "potato-like" plants in nature that are resistant to late blight. However, they don't breed with our potato varieties to bring resistance into our potato lines through natural crossing. Enter biotechnology:

DR. HELGESON TELLS HOW he is using enzymes to peel cell walls away from the interior of cells from potato leaves. The remaining "protoplast" interiors contain all the vital machinery of cells. He also peels walls from the cells of wild potato-like plants. Then Helgeson "fuses" the two protoplasts together, one from the wild and one from a modern potato. He fuses them using a chemical medium or with a zap of electricity. This brings together the genetic variability of two species into one somatic (nonsexually produced) hybrid cell.

Helgeson is growing these somatic hybrid cells, which started as simple leaf cells, into complete plants. Each cell in plant and animal life contains the "genetic instructions" to construct the complete body from which it comes. Helgeson is selecting the somatic hybrid plants for resistance to "late blight," the fungal disease responsible for the historical 143-year-old plague that until now has foiled mankind. A win for agricultural biotechnology.

CONSIDER YOUR PROBLEM IF YOU ARE A PLANT BREEDER trying to perfect a superior tree. Let's say you cross two oak trees. Your object is to blend desirable characteristics of the two trees. You plant an acorn from the cross. Then you wait 10 to 15 years until the cross produces its own acorns so you can see whether any desirable traits are going to be passed on to future generations. Using classical breeding techniques and selection processes, you won't live through very many generations of trees to see whether you have achieved success.

Or let's say you want to cross an elm with an oak to blend the good characteristics of the two trees. Forget it. They don't cross.

Any wonder relatively limited work has been done on forest tree breeding, although forest trees are very important to our livelihood through production of lumber, pulp, firewood, and fiber?

NOW COMES BIOTECHNOLOGY TO RESCUE TREE BREEDING. Dr. Brent McCown of the University of Wisconsin tells what he is doing about a tree problem. The problem is how to make big plantings...plantation plantings...of poplar trees, used for pulp. The young poplars...the 1st to 4th year...are very poor competitors against weeds. If you have very many weeds in the plantation planting, you can easily lose half your young trees. You could use weed killers on the weeds, but that would also kill your young poplars.

BUT IF THOSE YOUNG POPLARS WERE RESISTANT to weed killers...then you could spray, kill the weeds, and the young poplars would get off to a robust start. Dr. McCown went looking for a gene resistant to weed killers, one that he could introduce into poplars. Where do you suppose he found the gene? In a soil bacteria.

He uses the technique Dr. Helgeson described to strip away the walls of poplar cells. Then he mixes the interior protoplast with a soil bacterium cell which imparts its DNA into the poplar cell. The DNA carries resistance to the weed killer. From these cells McCown produces young poplar shoots.

Dr. McCown takes the young shoots, which he can grow this way in large numbers, and puts them in a growth medium that contains the herbicide chemical. The shoots that live are resistant to the herbicide. He grows out those plants, then uses tissue cloning to greatly increase the number of shoots containing the resistance to weed killers. Next he grows these shoots into young trees in the greenhouse and sprays them with weed killer herbicides. Those that live give him tree stock ready to plant in large numbers in tree plantations.

SINCE TREE GROWERS WANT LARGE NUMBERS OF SEEDLINGS at a low cost per seedling, the next step is to move into clonal propagation using nodule cultures. They have a high capacity to regenerate. Another automated mass technique is to put artificial seed coats around embryos so you handle them like seeds. Lots of work is being done on this in the tree industry, says Dr. McCown.

McCOWN'S TECHNIQUES ALSO INTRODUCE THE POSSIBILITY of testing various new weed herbicides that will kill weeds yet do no harm to trees or the environment. He and others are also working to shift strengths from one tree species into another.

In short, "biotechnology has introduced extremely exciting possibilities into tree reproduction with incredible opportunities to improve trees," sums up Dr. McCown. It means much greater efficiency in the production of trees, lumber, pulp, firewood, and fiber. Much shorter production periods for forests. Great diversity of products. And important environmental benefits by getting away from introducing chemicals into the environment.

MINNESOTA SCIENTISTS ARE TRYING TO UNDERSTAND why there is so much variation in plants grown from cells of the same plant when using tissue culture. They want to be able to speed up the variation when they want it, and slow it down when they don't want it. Meantime, they have learned how to harness this variability in corn.

Minnesota scientists have put two amino acids--lysine plus threonine--into the tissue culture growth medium. They find, after screening thousands of cells, that they have isolated a corn line resistant to the two amino acids. What they also find is that the corn line carries a 30% higher content of methionine, another amino acid. Methionine is important in livestock and human diets.

This corn strain, high in methionine, has potential benefits in poultry rations. Feed manufacturers in the U.S. spend $200 million a year supplementing poultry rations with synthetic methionine. China is interested, since it is just getting into mass poultry production. Brazil and Mexico are interested because of their bean-corn diet. When beans make up a large proportion of the human diet, methionine is short.

Corn provides 14% of the world's edible protein; therefore, the quality of corn protein is important, observes Prof. Ronald L. Phillips, University of Minnesota.

THE CORN GENE THAT CARRIES HIGHER PRODUCTION of methionine has been cloned, says Dr. Phillips. The next step: Transfer the gene to soybeans, which normally are low in methionine. It is now possible through new developments in agricultural biotechnology.

"We are learning more about crop plants at a faster rate than we have ever known before," observes Dr. Phillips. "Biotechnology is giving us a new understanding of genes and their functions and a new understanding of biochemistry," he says.

Scientists are now using a new technique for mapping DNA segments for gene sites, making it easier to transfer wild plant traits to our crop species.

"THE TROPICS provide a rich diversity of plant material...potentially useful fruits and medicinals that we don't know about today. This is a fertile area, ripe for study. Many people around the world are beginning to work on it," says Dr. Paul Read, head of the Horticulture Department, University of Nebraska.

Dr. Read is cloning large quantities of blueberry plants that are more resistant to cold. He will also try to develop blueberries that will tolerate less acid soils, thus expanding the natural growing areas for blueberries. He is advising work to develop blueberries with more resistance to the weedkiller 2,4-D.

HOW BIOTECHNOLOGY IS CHANGING ANIMALS

SCIENTISTS ARE BUSY SNIPPING vital gene "messengers" out of viruses to make vaccines. Viruses can't reproduce themselves. Instead, they invade host cells and a gene messenger from the virus tells the host cell to make the ingredients needed for virus reproduction. By changing one of the virus gene messages, we make the live virus incapable of commanding the host cell to manufacture the vital ingredient.

We then manufacture and inject the live virus vaccine containing the altered virus. Still, the host animal recognizes the outside coat of the virus, which hasn't been altered, as an enemy and produces the antibodies to kill off the invader. From then on, the animal has immunity--has the bullets ever-present in the blood stream to shoot down the natural, potent virus, should it ever invade the animal.

LET'S LOOK AT AN ANIMAL DISEASE that we are taming through biotechnology. It's pseudorabies, a virus usually fatal to cats, dogs, rats, mice, and skunks. They don't get pseudorabies readily; but when they do, they usually become "dead-end" hosts, thus the disease is self limiting.

Hogs, though, are the big problem. They get pseudorabies readily, but the disease is less fatal in them, even though it does a lot of damage. The virus gets into the hog's nervous system, causing a kind of hog herpes, which inflames the brain and causes abortions, small litters, slow growth, and a high death rate in young pigs under 2 weeks of age.

PSEUDORABIES IS UNPREDICTABLE IN HOGS. The virus can loll around in a hog's nerve cells for months, causing the hog no grief. But in times of stress when the pseudorabies decides to go on a rampage, the virus invades hog nerve cells and the virus "messenger molecule" tells those nerve cells to "hop to" and produce an enzyme, thymidine kinase, TK for short. TK is essential to build new pseudorabies viruses. In an outbreak, the virus "messenger molecules" keep up a constant "drum roll" in the hog cells. The virus multiplies wildly and races around in the hog in overwhelming numbers, stomping on the hog's nervous system with very undesirable results.

But without TK, the virus is a milquetoast and doesn't--can't--continue to multiply or hide out in nerve cells. Scientists, using biotechnology techniques, have plucked from the virus DNA string the messenger that tells hog cells to make TK. What scientists have then is a "pussy cat" live virus vaccine. They inject it, but the altered virus can no longer deliver a "drum roll" message for the hog cells to make TK to produce more virus. Still, the hog--not knowing but what the pussy cat is the real, natural macho pseudorabies --calls out the virus bashing squad which knocks out the pussy cat virus in a jiffy.

FOLLOWING THAT, the hog now has a virus bashing antibody squad on hand trained to fight pseudorabies viruses. That squad continues to cruise around in the hog's blood stream and is ready to pounce on any virulent pseudorabies virus, should the hog later be exposed to the real disease. By the way, the chance of that "messenger molecule," for TK production, ever being put back in the live virus by nature when the altered live virus vaccine is injected into hogs is essentially zero.

One problem, though. Subsequent tests can't differentiate between a vaccinated hog and one infected with the real disease. So Donald Todd, senior vice president of SyntroVet Incorporated, tells what they are doing. The company is inserting a "marker" messenger in the vaccine. The aim: develop a test which can show whether the hog was vaccinated with the pussy cat or has the real disease.

That's the new, wonderful world of biotechnology at work.

NOW FOR A LOOK AT BIOTECH AND THE WORLD OF ANTIBODIES: Picture this, if you will: A "bad guy" pathogenic (disease-producing) organism invades your body. T cells, which originate from the thymus, under your breastbone, rush into hand-to-hand combat against the invaders. Think of them as "Mr. T" cells, tough and strong. B cells, which originate in the bursa of Fabricius, produce antibody bullets that strike down the invaders. Think of the B cells as the "bullet makers," as described by Dr. H. Graham Purchase, special scientific adviser of the Agricultural Research Service, U.S. Department of Agriculture.

THE T CELLS AND THE B CELLS TALK to each other and coordinate their attack against the invasion through small protein messages, called lympokines (body telegrams), sent through the blood stream. We have captured these proteins, purified them, identified their messages, and inserted them into bacteria to produce antibodies (disease fighters) in quantity, explains Dr. Purchase.

WE CAN EVEN FUSE a bullet-producing B cell, which has a short life expectancy, to a tumor cell that can live indefinitely. This tumor cell, in turn, can be grown into large numbers of cells, all turning out the single antibody bullet (monoclonal antibody) which usually is highly specific in what it attacks. This leads to tests that can distinguish between antigens (invaders that incite immunity) that are closely related, thus making it possible to test for and diagnose different viral or bacterial diseases, says Dr. Purchase.

ANOTHER DISEASE-FIGHTING MECHANISM in the arsenal is to use biotechnology techniques to increase the natural ability of animals to fight off diseases. In this case the genes of the animal are changed so the "T" cells and the "B" cells produce a faster, more overwhelming response to a virus invasion. That may be the answer for diseases when we don't know whether a vaccine will work. That would include African Swine Fever, a fatal disease of swine but not of other animals, says Dr. Roger Breeze, director of the U.S. Department of Agriculture Plum Island Disease Center.

Plum Island, off the end of Long Island, not connected by land to the mainland, is the Nation's disease center for handling virulent foreign animal diseases such as foot-and-mouth disease, the most infectious disease known. Scientists must commute by boat to Plum Island, change clothes going into the laboratory, and take showers and scrub down when they come out.

Foreign diseases are always a threat. For example, 2 percent of our feedlots now feed 78 percent of the Nation's beef cattle, says Dr. Breeze. A disease outbreak, with that concentration, could strain the U.S. long-standing policy of slaughter and eradication of infected and exposed animals. Vaccination might be necessary. That depends on having good genetically engineered vaccines for emergencies.

SO OFTEN WE HAVE HEARD: What's more important, heredity or the environment? Well, we're about to come closer to the answer for animals. What makes this possible is that we now know how to clone genetically identical animals. Three years ago they said it couldn't be done.

We're doing it now, using biotechnology techniques, with rabbits, sheep, and dairy animals. Dr. James M. Robl, University of Massachusetts, collects an embryo in early development as it first starts to split...into eight cells... separates them, removes the nuclei, and injects these nuclei into host female eggs that have had their nuclei removed, to produce identical offspring in surrogate mothers.

What you can do then, with identical cloned animals, is conduct experiments by varying the environment. Since you start with genetically identical animals, any variation in test results should be caused by the environment.

ALTHOUGH ANIMAL CELLS, like plant cells, each have the instruction manual to produce a complete body, scientists have been able to bring this about in animals only by using early embryos. Even there it works only about once out of 100 times, so far, says Dr. Robl.

"It's high cost; but once you get the animal you want, it is there from then on for good, and you can write off the cost over future generations," observes Dr. Robl. Still, this work is more likely in beef cattle than in hogs by the nature of the surgical work required.

EXPERIMENTAL WORK also is going on to shift genes from one animal line to another to produce "transgenic animals." The purpose: see if important qualities of one kind of animal can be transferred to another. That research is slow and costly; more likely in hogs than in beef cattle, says Dr. Robl.

ONE OF THE MOST TALKED-ABOUT BIOTECH DEVELOPMENTS is the mass production of animal growth hormones. Scientists, using genetic engineering techniques, insert the growth gene, say from hogs, into the DNA of bacteria. The bacteria with the rDNA (rearranged DNA, called recombinant DNA) are fermented in solutions and become "living factories" producing the swine somatatropin (ST) growth hormone.

The pST hormone (porcine somatatropin) is then injected into hogs as a supplement to their natural growth hormone produced by their pituitary glands.

Bovine growth hormone, bST (bovine somatatropin), is produced in a similar way. It is injected into cows, causing them to produce more milk--which they do on less feed per 100 pounds of milk produced. Cows handle it well as long as they are fed more heavily to maintain their higher level of milk output.

NEW AGRICULTURAL BIOTECHNOLOGY PRODUCTS ARE ON THE MARKET; others are just around the corner--and they can have a substantial impact on agriculture. Take bST for dairy cattle. It is expected on the market in the next year or two. The bST is a natural hormone that cows produce already, more at the beginning of the normal 10-month lactation milking period than at the end as milk output tapers off. Four companies are working feverishly to bring bST to market. The idea: boost milk output by supplementing this natural hormone, particularly in the last two-thirds of the lactation, with the injectable genetically engineered bST hormone produced through fermentation.

TEST RESULTS THUS FAR SUGGEST that you can raise milk output about one-fourth and feed efficiency about 8 to 11 percent using bST, says Dr. R.J. Kalter, Cornell University. It takes more feed, naturally, as cows are producing milk at a heavier rate; but you get more milk per pound of feed. In tests, researchers have observed no cow "burn out" after two lactations. The milk produced is unaltered in its makeup, says Dr. Kalter. Ordinary milk already has some bST in it.

AND NOTE THIS: pST for hogs may be close behind; possibly on the market in 4 years. The potential there: rate of gain, up 10 to 20 percent; feed efficiency, up 15 to 30 percent; and backfat 70 percent less, Dr. Kalter says. Meat cuts in test hogs, for example, show much larger lean sections and an astounding dropoff in the fat layer. The increase in gain and feed efficiency "could put hogs in the same position with poultry in efficiency, with a pound of gain in pork from less than 2 lbs. of feed," says Dr. Kalter.

Such developments will cause changes in feed use, feed grain acreages, and numbers of farmers, says Dr. Kalter.

"Increased information will be crucial during adoption of significant biotech inputs," says Dr. Darrell Hueth, chairman, Department of Agriculture and Research Economics, University of Maryland.

THE bST HORMONE FOR BEEF may become practical. Right now, the hormone must be injected daily for best results, which is not practical for handling beef cattle or for hogs. But the biotech companies are working on a "sustained release" hormone to bring it into practical range for injection, say once a month rather than every day. "I have every faith we will be on the market with sustained release products," says Dr. James Gramlich, director of agricultural research, American Cyanamid Company.

"Biotechnology is going to make it possible to produce things in agriculture we couldn't produce before," Dr. Gramlich predicts.

This could even cause dramatic changes in international agricultural trade, says Dr. Hueth.

IS THE MEAT OR MILK produced from animals given growth hormones safe? "A resounding 'yes,'" replies Dr. Larry D. Satter, USDA scientist at the Agricultural Research Service Laboratory, University of Wisconsin. "It is one of the safest products we can imagine in the livestock industry." Here's why, as explained by Dr. Satter:

The amount of growth hormone in milk or meat is not increased at all, or negligibly, over the natural growth hormone already there, produced by the pituitary gland. The growth hormones are proteins that are digested and rendered useless in human digestion, anyway. Besides, animal growth hormones do not become active in people--even if injected directly into our bodies.

AN UNEXPECTED NEW DEVELOPMENT HAS JUST ARISEN with growth hormones. Dr. Keith W. Kelley, immunologist from the University of Illinois, explains it. Kelley, and colleagues at Pitman-Moore, Terre Haute, Ind., have discovered that pST stimulates the disease-fighting immune system of hogs in a way not known before.

First look at how hogs--or humans--fight disease: The macrophage cells that circulate in the blood, reach out with a long foot and pick up invading bacteria. The macrophage cell oxidizes and destroys the bacteria. As it does this, the macrophage hangs the coat of the vanquished bacteria on its own outer surface. Let's say it's a "red coat." The macrophage then goes looking for "helper T cells," which are the troops used in fighting disease organisms.

THE RED COAT ON THE MACROPHAGE alerts the T cells that the body has been invaded and that "the red coats are coming." The macrophage and the T cells "talk" to each other through protein messages. In effect, the macrophage says "we've been invaded; the enemy is wearing these red coats; call out the T cell troops and attack."

The T cells call up the troops by the millions (they make them). The alerted T cells say to the macrophage, in effect: "Stick in there Mack; we'll send out gamma interferon messages alerting your macrophage buddies to round up and oxidize these red coat guys." They go to war together. The gamma interferon messages energize the macrophage cells throughout the body and they devour the red coats with a frenzied gusto. The helper T cells surround the enemy, shoot them down when they are hiding in body cells, coat them alerting the macrophages where they are, and do all sorts of things to help win the war.

ONLY RECENTLY HAS DR. KELLEY DISCOVERED that pST does something important to stimulate the macrophage cells in hogs. Earlier, it was thought that only the gamma interferon messages from T cells stimulated macrophage cells. "I feel very comfortable in telling you that in our experiments it is indeed the pST growth hormone, and not some other contaminating molecule, that has a dramatic effect on increasing macrophage activity in hogs," says Dr. Kelley.

"THIS IS JUST THE TIP of the iceberg," Dr. Kelley says. "We are beginning to realize that growth hormones have an impact on the immune system that we had not thought of in the past. This is a tremendous advance to know that the genetically engineered pST contributes importantly to the work on immunity."

We have a startling lack of knowledge about the immune system of farm animals, says Dr. Kelley. He points out that there are differences between breeds of hogs in their ability to produce antibodies to attack selected pathogenic bacteria, which we may now understand better. "The discovery regarding the effect of pST on immunity illustrates the potential of engineering genes in farm animals to improve resistance to important animal diseases," he says. And this can be important in human medicine.

ONE OF THE MAIN ADVANTAGES that biotechnology brings is speed. It is speeding up research through better understanding of how diseases develop and do their damage. "We can answer questions more quickly, more definitively, and answer questions that weren't practically approachable a short time ago," comments Dr. Harley Moon, with the USDA National Animal Disease Center in Ames, Iowa.

Dr. Moon points out that we now know, for example, how the E. coli bacteria work to cause diarrhea in pigs and calves (and in humans). The bacteria reach out with tiny protein finger-like spikes, called "pili," and grasp the receptors of the outermost epithelial cells of the intestinal tract. You can treat the disease with chemicals, antibiotics, and vaccines that "block" the pili from grasping the receptors of the tiny microvilli intestinal cells.

YOU CAN PROTECT THE PIGS by vaccinating the sows. The sows produce an antibody in their blood which is passed through the milk into the intestines of the suckling pigs, blocking the grasp of the E. coli pili fingers. However, after weaning, pigs often become infected and lack the protection of the mother's milk.

Vaccinate the pigs by injection? You can. But the antibody produced by the vaccine is primarily in the pig's blood stream, while the problem is out in the intestine where the E. coli are grabbing onto the receptors of the microvilli. Treating pigs with oral vaccines is possible, but those vaccines produce poisonous toxins harmful to the pig.

Now comes the solution: Using biotechnology techniques, scientists are working to construct E. coli bacteria which carry the gene messages that cause the pig to develop antibodies in the intestine. But the bacteria do not contain the gene for making toxins. Dr. Moon thinks that E. coli oral pig vaccines will be available in 3 to 5 years.

THERE'S ANOTHER BIOTECHNOLOGY SOLUTION to this E. coli drama. Some pigs are resistant to the bacteria. Their intestinal cells don't have the "hand hold receptors" where the E. coli pili grasp the cells with their spiny fingers.

This resistance is inherited through a "recessive" gene that gives the message to construct intestinal cells with no "handholds." The pig needs to inherit the recessive gene from both the mother and father for the message to work. The lucky pig gets better protection than from either drugs or vaccines.

We have known this for 10 years. But there has been no easy way to select the recessive gene-resistant breeders. But now, through biotechnology techniques, it is possible to use "marker DNA" that are closely linked to the gene messages for resistance, Dr. Moon explains. Next step: Clone the marker DNA and use it as a diagnostic probe to select resistant breeders. Following step: Transfer genes from pigs resistant to E. coli directly to swine embryos to develop hogs that will pass along the resistance to their offspring through natural breeding.

THINK OF THE BENEFITS OF THAT VICTORY for biotechnology, explains Dr. Moon: It will reduce animal suffering (millions get diarrhea every year). It will reduce the use of chemicals and antibiotics. It will reduce chemical residues in food. It will diminish antibiotic-resistant bacteria in our food supply. It will reduce the cost of animal production. And it will open up more options for treating human diseases, such as pilus-based vaccines to prevent E. coli infections in humans.

WHILE THE BENEFITS OF BIOTECHNOLOGY may be truly spectacular, we must be patient, cautions Dr. Keven S. Guise, University of Minnesota. He points out that we must first isolate single genes for specific traits before we can successfully clone these genes--such as raising kilogram quantities of gene products through fermentation "bacteria factories."

Gene transfer, where we transfer a novel gene from one species to another, is in its infancy. The transfer success rate thus far in sheep, rabbits, and pigs, ranges from 2 to 15 percent, Dr. Guise points out. "We are still severely limited by our knowledge of basic biology, biochemistry, and metabolism of domestic animals," he says. "The potential of genetic engineering to produce rapid improvements in the economic traits of domestic animals will take years to bring to fruition while we do basic research to define systems and the generation times of the recipient animals."

The competition is intense, Dr. Guise, points out and adds: "Transgenic animals will find a place in the food supply of man within the next decade."

DR. SUSAN K. HARLANDER, Food Technology professor at the University of Minnesota brings biotechnology into everyday perspective when she talks about making cholesterol-reducing dairy starter cultures; making starter cultures that will inhibit bad-bug pathogenic microorganisms; making high-value proteins out of waste whey; improving farm income through biotechnology; and constructing improved yeast strains for use in brewing, baking, and winemaking.

Dr. Harlander is using fermentation to develop natural flavors for the food industry. "Consumers want natural ingredients," she stresses. She is also working to make useful high-value products out of the lactose and protein in whey, essentially a "throw away" product now. Other work in her area: A quick test for listeriosis, a food poisoning caused by listeria that grow even at refrigerated temperatures. Present tests take 2 weeks to complete.

Dr. F. Ann Draughon, University of Tennessee, also told the Raleigh conference how she uses biotech to make faster tests for bacteria in contaminated food. China invited her to share her expertise.

FOOD PROCESSING IS ONE OF THE MOST PROMISING arenas for biotechnology, with exciting work under way. Dr. Rafael Jiminez-Flores of the University of California at Davis is improving proteins.

Dr. Sharon P. Shoemaker of Genencor, Incorporated, San Francisco, is working with commercial production of enzymes.

Dr. G.H. Richardson of Utah State University is improving cheeses. Scientists in food technology are working on fermentation, safe packaging, food additives, nutrition, diet, and health.

Dr. William E. Sandine of Oregon State University, is exploring lactic acid uses for flavoring foods, improving intestinal health, making antibiotics, and enhancing nutrition. He is also developing ways to "inhibit pathogens" in fermentation production. "Fermentations get viruses, just like people do," says Dr. Sandine. He is also participating in a large test with several hundred people to determine effects of biotechnology products on reducing blood cholesterol levels.

IS IT SURPRISING THAT CELLS ARE LIKE PEOPLE? Some cells are good readers of gene messages; some are not. Some cells are overachievers; some are underachievers--even though they get the same message. Scientists are trying to find out why. Call it "motivational microbiology," suggests Dr. Thomas J. Montville of the Department of Food Science at the New Jersey Agricultural Experiment Station. "Rather than pumping new information into cells, we're trying to understand what causes cells to act, or not act, on the information they already have," says Montville.

DR. MONTVILLE IS WORKING WITH lactobacilli, the "blue collar" organisms that ferment foods such as cheeses, sauerkraut, and pickles. Aim: "improve fermentation processes, invent new ones, and produce 'natural' flavors, pigments, and modifiers to replace 'artificial additives.'"

LACTOBACILLI, "THE FERMENTERS," ARE UNDERACHIEVERS. They have the genetic potential to produce a broad array of products. But by and large they are content to do one thing: produce lactic acid. Let's say lactobacilli eat 20 units of sugar. They invariably convert 19.9 units to lactic acid and less than 1/10th of a unit to diacetyl and acetoin, two chemicals that give dairy products their "buttery flavor."

DR. MONTVILLE IS DISCOVERING how to "motivate" the lactobacilli to make more buttery flavor compounds instead of lactic acid. He has found a clue: the acidity of the fermentation environment. By controlling the acidity around the lactobacilli, Montville has been able to greatly increase the production of buttery compounds. If the acid around them is low, the lactobacilli make lactic acid; if the acid around them is high, they make buttery compounds.

Dr. Montville has also found the cells continue to convert food to flavor compounds long after they have stopped growing. By feeding the cells at that point, Montville has motivated cells to increase buttery flavor production by 700 times. That biotechnology technique, he thinks, will lead to a strategy to use with other organisms to increase the production of many valuable food components.

FOOD PROCESSING IS A BIG INDUSTRY and fermentation techniques are used extensively to convert farm products into various food products--cheese, yogurt, buttermilk, beer, bread, wine, pickles, natural flavors, colors, and the like. Biotechnology is active in making fermentation starter cultures more efficient, stronger and more resistant to virus infections of their own, and capable of producing new and exciting food products, as well as pharmaceuticals--which is a large fermentation industry in itself.

RECOVERING PRODUCTS FROM FERMENTATION is a difficult and expensive process. Dr. Bonita Glatz, professor of Food Technology and Microbiology at Iowa State University, points out that fermenters are always looking for ways to improve the economics of fermentation production, an area where she is doing research. This research requires a team approach, with engineers, geneticists, microbiologists, and food processing experts working together.

FOOD PROCESSING IS ONE OF THE AREAS where Purdue University, for example, has not been able to meet the demand for graduates this year, says Purdue's Dean of Agriculture Robert L. Thompson.

KEVEN OCHSNER, FFA NATIONAL SECRETARY, points out that there are 48,000 new openings yearly for college graduates for careers in food and agricultural sciences. "We are excited about the role FFA is playing in preparing for these openings and the role of agricultural biotechnology in making more openings possible," he says.

IN OTHER FOOD PROCESSING DEVELOPMENTS, Dr. Hans P. Blaschek, University of Illinois Department of Food Science, is using genetic engineering with genes that break down starch. He is developing better fermentation processes, particularly for making butanol from corn starch. Butanol is a higher value product than the ethanol made from corn, which is used in some gasoline fuel mixtures. High fructose corn sweeteners, now used extensively, are from a fermentation industry that scarcely existed 10 years ago.

DR. HARLANDER speaks of the possibilities for building higher value products from farm commodities...especially from proteins...and using farm surpluses through biotechnology. "It is my strong feeling that biotechnology will have a very dramatic impact in helping reverse the loss of profit in rural America," she states. Dr. Harlander also believes that we will be able to genetically engineer cows that will be living factories for producing products in their milk such as TPA, a new biotech product, now given to heart attack victims.

LET'S SAY YOU HAVE A NEW AG BIOTECH PRODUCT coming on the market. It promises to overcome a problem on the farm, reduce costs, save on labor, and increase output. Well, it "ain't nothing yet" until farmers feel they are able and ready to use it. Dr. Thomas Hoban, North Carolina State University, outlines the adoption process:

Farmers look to see if they can work the new thing into existing practices and know-how, try it on a small scale, see the results, and make a profit on it.

Communication is important. Farmers usually hear about a new thing through the mass media. Their ears perk up. Some, the early adopters, go charging in. Others look to friends, neighbors, and trusted advisers before putting a toe in the water. Late adopters almost have to be dragged into the arena. Some don't make it. What do we do about them?

"THE MOST OBVIOUS AND IMMEDIATE EFFECT of new technology is that its adoption increases agricultural productivity," comments Katherine Reichelderfer, Economic Research Service, U.S. Department of Agriculture. As agricultural productivity has increased through new agricultural developments in the past, farmers have been displaced. This is a result of the fact that fewer farmers are needed to produce the same quantity of goods, explains Reichelderfer.

EARLY ADAPTORS ARE USUALLY BIGGER OPERATORS, better educated, more risk oriented, better managers, more tuned into the communication process, and have an itch to do things differently and better. That's usually how they got to be bigger and better. If there's any "windfall" to be gained from the new thing, they get the bulk of it. Late adopters may be worse off. Increased output may depress their prices while they still are living with the old, higher costs.

It was always thus. It's not likely to be any different with ag biotech products, except profit margins are narrower now--purchased farm production items make up a larger share of farmers' costs. Late adaptors can get hurt quicker and have more pain. That can affect rural communities also. That makes a bigger challenge for public institutions, including land-grant universities and community institutions, says Dr. Ronald D. Knutson, Texas A&M University.

"NEW TECHNOLOGIES ARE ADOPTED SLOWLY, allowing time for farmers to adjust," Reichelderfer observes. A range of public policies and programs are also available now, either to help increase the demand for agricultural commodities, thereby maintaining the need for production by many farmers, or for easing the transition of farmers to other occupations, says Reichelderfer.

THROUGHOUT OUR HISTORY AS A COUNTRY, which started as an agricultural nation, farmers have been enticed to move from farms into manufacturing, business, and service industries. There they have helped produce the products and services that have helped this country expand, grow strong and vigorous, and become the most affluent in the world.

Meantime, new agricultural developments (ag biotechnology being the latest) eased the work life of farmers and increased agricultural output and efficiency. Now 2 percent of the Nation's people farm and produce the Nation's food and fiber--with enough extra production to make the United States the world's leading agricultural exporter. Without that continued transition of people from agriculture to other careers, this national growth could not have happened.

The poorest countries in the world include those who require the highest concentration of people in farming to produce food and fiber.

LOOKING OVER THE SHOULDER OF BIOTECHNOLOGY

AS WE DEVELOP AGRICULTURAL BIOTECHNOLOGY, we are dealing with the basic nature of living things. The newness and the mystery give us a special obligation to consider public perception, says Dr. Kenneth A. Gilles, assistant secretary for Marketing and Inspection Services, U.S. Department of Agriculture. An informed public will be the key to understanding and accepting the development and testing of biotechnology products, Dr. Gilles stresses.

USDA, which shares Federal regulatory responsibilities over biotech testing and development, is determined to provide safeguards and to support research and product development in agricultural biotechnology without stifling innovation. "USDA wants to work with scientists and industry to increase the understanding of science so we can preserve and use the benefits of biotechnology now and for future generations," says Dr. Gilles, who heads up USDA regulatory activities.

THE U.S. DEPARTMENT OF AGRICULTURE IS GOING ALL OUT to provide sound, reasonable, and effective regulatory oversight for biotechnology. "It's a cooperative project all across Government, with the aim of helping assure the public of safe biotech products with dispatch," says Dr. Al Young, USDA director of the Office of Agricultural Biotechnology.

USDA has named a far-ranging Agricultural Biotechnology Advisory Committee of national experts to assist. In addition, USDA is doing extensive biotech research itself.

Early on, USDA determined that existing statutes were adequate for its job of regulating biotech, says Terry Medley, Esq., director, APHIS biotechnology and environmental coordination staff.

"GOVERNMENT HAS THE DUTY TO PROTECT public health from unsafe products...and the responsibility to do so without hampering the innovative spirit of science and industry," says Mary Ann Danello, Food and Drug Administration, which shares with USDA and the Environmental Protection Agency the prime responsibility for regulating agricultural biotechnology. "We want to foster, not impede, the development of biotechnology," Danello says.

BIOTECH IS IN A BATTLE FOR PUBLIC ACCEPTANCE. That's not new. Fred Smith, president of the Competitive Enterprise Institute, relates that the Greeks told a mythical story about Prometheus bringing technology to mankind and being condemned to endless torment for doing so.

Maybe the Greeks had something. The person who invented modern day hot air blowers for drying hands in public restrooms should be condemned to use them. Likewise, the inventor of those little plastic bags that you strip off rolls at the produce counter in supermarkets should be condemned to spend a whole day opening them.

THE VALUE OF BIOTECHNOLOGY IS OBVIOUS, Smith contends. "Without the slow accumulation of wisdom which allowed us to improve the genetic aspects of both plants and animals valuable to mankind, mankind would today be living a brutish life."

Modern public policy raises the question of who shall determine what "boxes" will be opened, says Smith. He argues that those "choices are best made by private individuals held fully accountable for their actions." He says that by contrast, "A political approach to risk management is not only costly but risky to mankind's safety." Smith laments that for now most people believe that we "must impose 'wise' political regulation over the biotech field."

MISTAKES ARE INEVITABLE, Smith acknowledges, no matter who opens the boxes. There is no such thing as a risk-free society. But he sees this scenario: A political institution makes a false approval of a biotech product. The agency is severely criticized for its mistake (those pointy-headed Federal dummies). Hearings are held (heads roll). The agency's ability to open future doors is curtailed (a tortoise syndrome sets in: Pull in your head; and go slow).

A false disapproval, however, that keeps a biotech product off the market, has far less chance to evoke public outcry. Those people placed at greater risk by such a false disapproval may well be unaware of the consequences. "Those who die and their loved ones may never know they died unnecessarily," Smith says.

WHAT IF BOXES ARE OPENED BY PRIVATE INDIVIDUALS held fully accountable for their actions? Laws, procedures, risk of company and product reputation, concern for public welfare, private and scientific integrity, and threat of economic obliteration evoke satisfactory restraint and hold individuals in check. If individuals err, the abused can go to court and get their pound of flesh, says Smith.

SMITH'S BOTTOM LINE THESIS: "Biotechnology may very well lower the need for energy drilling...chemical fertilizer and pesticide/herbicide production... land tilling and other crop management activities...as well as storage and spoilage concerns--all of which have safety as well as economic consequences. Those gains are at risk if we continue to expand the political control over the evolution of biotechnology."

OTHERS ARGUE FOR STUDIED CAUTION, more concern about possible biotech effects on farms, rural areas, and on people. One who recommends caution is Jack Doyle, Environmental Policy Institute. He is concerned about biotech shorting "common sense" biology; multinationals "owning" biotechnology; patenting animals; and shrinking gene pools to the point where homogeneous plant populations become more susceptible to potential disaster, such as our 1970 experience with Southern Corn Leaf Blight. The blight spread from the South to most of the eastern half of the country within a few weeks and hit our susceptible hybrid corn crop hard.

HOWEVER, DR. FRED DAVISON, UNIVERSITY OF GEORGIA, worries that our national attitude toward biotechnology is driven by fear. He deplores setting policy toward science in the voting booth. His example of bad policy: The Delaney clause. Agricultural biotechnology, he says, is far safer than what we've had. But we are regulating ourselves out of the science, he thinks.

"It's a myth that past accomplishments assure the United States of continued dominance in the world," Davison says. We lost No. 1 in banking and automaking to Japan, he relates. Now planning in Japan has turned to biotechnology. "We're No. 1 in the world in producing new information," Davison says, "But our pipelines to use that information are clogged with so much ignorance, regulations, and fear that we can't get it done."

INDUSTRY AND THE SCIENTIFIC COMMUNITY have actively participated in developing Federal biotechnology regulations over the last 5 years, states Allen J. Dines, Director of Business Development of the Agricetus company. "Tremendous effort has gone into developing a coordinated framework. It has been a learning process for all," he says. "The biotechnology industry has supported and continues to support the Federal approach to regulation."

Industry depairs at the thought of having to meet a maze of conflicting State and local biotechnology regulations in addition to Federal regulations.

"THE SPECTACULAR NEGATIVE CONSEQUENCES of biotechnology suggested by some critics of the coordinated framework have all proven totally hypothetical," Dines states. "As an environmental issue, biotechnology pales relative to demonstrated environmental problems society faces in cleaning up hazardous wastes, in controlling water and air pollution, and in safe siting of solid waste facilities, to name a few," says Dines.

"THE OBVIOUS SAFETY OF BIOTECHNOLOGY is becoming increasingly apparent to the general public," says Dines. This is not the results of words of reassurance, but rather the result of growing public realization of actual events:

"More than a decade of safe laboratory research experience with recombinant organisms...several decades of safe experience with field testing and use of conventional plant and animal breeding...several decades of safe experience in development of new industrial microorganisms for food and drug uses...and a rapidly growing number of successful 'environmental releases' of genetically engineered organisms since 1986."

KNOWLEDGE DISPELS FEAR, Dines observes. "In the face of experience to the contrary, the predictions of dire results from technology hand-wringers appear increasingly hollow. The public's increasing understanding that genetic engineering is not an environmental issue will characterize the coming years," states Dines.

COMMUNICATING WITH THE PUBLIC FOR A BETTER UNDERSTANDING OF BIOTECHNOLOGY

WITH THE NEW, WONDERFUL WORLD OF BIOTECHNOLOGY at work, would you believe that the big problem with agricultural biotechnology is public opinion...fear...and the belief that the genie is going to get out of the scientist's bottle? That's the main deterrent. Mainly because people don't understand biotech and how it works. They've seen too many monster movies. Nor do people yet grasp the vast potential of biotechnology. Nor do they fully realize that we are in fierce competition with other countries for maintenance of our technical superiority and our level of living.

The battle is in the laboratory. The battleground is biotechnology. The players aren't just the scientists in the laboratory and the regulators--the public and special interest groups are fully involved. The outcome is economic vitality and viability for the Nation.

"WE MUST IMPROVE OUR COMMUNICATION with the public on science and agricultural biotechnology," says Ken Farrell, vice president for agriculture and natural resources at the University of California. We can't divorce biotechnology from the society in which the results are applied, he says. Scientists themselves must take greater responsibility for communication. They're the ones who know the subject, its potential, and the meaning of their own work, he says.

"This communication with the public in the long run must focus on the societal restraints to biotechnology that manifest themselves in regulations--and may lead to reduced public funding, vandalism, and destruction of equipment," says Farrell. "The communication media in all its forms is crucial to this communication. We must foster in-depth reporting on science-induced adjustments," says Farrell. "Otherwise, we will talk at each other instead of with each other."

PUTTING A NEW BIOTECHNOLOGY PRODUCT on the market is not easy. Problems in the lab, as perplexing and as costly as they are, can sometimes pale by comparison with running the gauntlet of public perception in testing and bringing the product to commercial reality.

"Previous industries had the luxury of developing relatively free from public scrutiny until their products had a significant impact on the economy and society," observes Dr. Jerry Caulder, president of Mycogen Corporation, San Diego, Calif.

Biotechnology, since its start, says Dr. Caulder, has been held to an unprecedented standard of accountability. "The responsibility to communicate with the public is particularly acute for agricultural biotechnology companies ...companies must listen to the public's concerns, as well as communicate the industry's views," Caulder points out.

HOW DO YOU TELL THE PUBLIC ABOUT BIOTECH through the media? "Pack your message in 20- to 30-second sound bites," advises Dix Harper, WRAL-TV, Raleigh, N.C. You have two things to pierce with the general audience: "I don't know, and I don't care; ignorance and apathy," says Harper, who is president of the National Association of Farm Broadcasters.

HOW DO NEWSPAPERS approach science articles? "They are issue oriented, novelty oriented, and results oriented," says science reporter Monte Basgall, Raleigh News & Observer. "Give us your ideas," he says on behalf of science writers. "We need your help." But its tough to get an incremental advancement in technology reported, he says. If you have something visual to show, so much the better, he adds.

"IT'S EASY FOR THE PUBLIC to be negative if people don't understand something. That lack of understanding can turn into hostility, and hostility into mania," observes Bill Johnson, Regional Editor, Progressive Farmer. Help farm magazines explain biotech to farmers, he urges scientists and the biotechnology industry. "What people aren't up on; they are down on," Johnson says.

"NEVER HAVE SO MANY known so little about so much," is the way Charles B. Crawford characterizes the public's understanding of science. He should know. He was science editor of CBS and now is a prize-winning science reporter for CNN, Atlanta, Ga. "Send science broadcasters a synopsis of what you are doing; we'll be around to see you," Crawford tells scientists. But be prepared to tell your story in 1½ minutes.

WILL REPORTERS TRY TO "do you in"? Not many. But they may fumble the story if you don't explain the facts clearly. Bottom line: Reporters are in charge of the questions; you're in charge of the answers. Reporters report your answers. Tell the truth. Package the message you want told...in a few words. Don't be afraid people won't understand biotech. If you don't try to explain it, they'll fear it, distrust it, and be against it.

SCIENTISTS AREN'T ALWAYS THE MOST articulate communicators. Some are. But many are accustomed to a lifetime of speaking in the terms and language of their own specialty. It's a language the public often doesn't understand. Some scientists may stumble and appear uncertain when they try to "tell it in plain English." "Learn to explain it to your grandchild," advises Dr. Tim Wallace, public policy specialist at the University of California.

Instead, some scientists often wish that the outside world would just go away and let them work at what they are doing--especially if they have talked with a reporter who then badly garbles the story, perhaps making the scientist look foolish to his colleagues. That can be stark humiliation to a scientist. Worse yet, perhaps, is the fear of talking with the media too freely and too often and being tagged by colleagues as a headline grabber.

THE INFORMATION MEDIA HAVE THEIR PROBLEMS with scientists. "It's a tall order for most reporters to deal with biotechnology," says Everett Landers, executive editor of the prize-winning Reno Gazette-Journal. "It's not easy for the media to deal with scientists and pierce the veil," he says. His advice to scientists: "Give the media trustworthy information; they will then make good decisions."

"THE PUBLIC DOES FEAR SCIENCE, and it fears the risks that scientists will take to pursue their own ends," says Landers. What the public is concerned about is perhaps not so much what scientists are working on, but the fear that they might skirt the rules and run around regulations. One publicized incident tends to make all scientists suspect.

GARY SACK OF THE CALIFORNIA FARM BUREAU NETWORK has covered every major agricultural story in California for nearly 10 years. He observes that "many people aren't compelled to learn about biotechnology unless there is a crisis."

Sack tells scientists, "if there's nothing to hide, a free flow of information can do nothing but help." He wants scientists to know that he and other broadcasters are always available. Broadcasters, in turn, want to know where to turn when they need to talk with scientists to fill in their own background and get advice on a new development.

SACK SPEAKS FOR OTHERS in the broadcast media with his advice: "Be open, be honest, be understandable," he urges, "and to get your message across to the public don't fall in love with numbers, graphs, and tables (the very basic language of science). They are confusing to most people," says Sack.

"KEEP IN MIND THAT ALMOST ALL MEDIA PEOPLE are generalists," advises Bill Hillman, Station KPIX, San Francisco. "Science and biotechnology are foreign to most reporters. The first job of that reporter is to try to understand your subject."

Hillman is a veteran TV reporter who has a special interest in science and technology. He emphasizes that "TV exists on pictures that move and do things with interesting results. The TV reporter tries to visualize the picture that will illuminate the subject meaningfully."

Hillman tells scientists, "When you work with a reporter, try to visualize how to tell your story with pictures...and how to do it with things that move. The more suggestions you can offer, the better. And don't count on more than 1½ minutes of air time!" Impossible? Well, no. It happens every day in every TV station across the land. Face it: That's the way it's done. The scientist and his or her work in biotechnology is competing with every other piece of news that moves with pictures on that day; not just competing to get on the air, but competing to communicate a message to a "laid back" audience busy thinking of other things.

IN TODAY'S SCHEME OF THINGS, your audience will talk back, and fully expects that right, adds Len Richardson, editor of the California Farmer, Agrichemical Age, and Agrichemical News--and former national president of the American Agricultural Editor's Association. For biotech companies, Richardson's advice is: "Make the public a part of your product plan. Communication starts at the top of the company and is part of a communication plan."

Adds Richardson: "Public perception is a stronger reality than a scientific fact." That may be difficult for a trained scientist to accept, but that's the real world.

NO QUESTION, A HURDLE TO BIOTECHNOLOGY PROGRESS is public understanding and the public perception of biotechnology, its benefits and its risks. How can those in biotechnology pursuits communicate better with the public? Mike Gray, North Carolina State communications specialist, has this advice for scientists:

Get your act together before you do a media interview...don't go into an interview until you feel good about having your message together...condense your broadcast message into 20 seconds, make it clear and precise...avoid technical terms that the public doesn't readily understand...be ready with your answers for the "downside" questions...think up some visuals for TV; they make the story for TV--talking heads won't do...help the reporter understand it; if reporters don't understand it, they can't report it so the public will understand it...have 3 or 4 questions to suggest for the interview...be honest...and never say anything off the record to a reporter.

AND NOW MORE ADVICE FROM THE MEDIA: Farm broadcasters are looking for "good news" without overlooking the bad, says Ed Slusarczyk, of Ag Radio Network, Inc. Utica, N. Y. "The public is confused," he says, "and farm broadcasters are looking for facts. Sum them up in 1 minute for broadcasts--110 words," he advises. "Forget the scientific vocabulary."

In a farm broadcast you have a dual audience: "Help the farmer manage his enterprise and make more money, and explain it to consumers," says this farm broadcaster, who was selected as the Nation's best in 1986.

"THINK OF THE MEDIA AS THE PUBLIC. The media represent the public's interest," says Kitta MacPherson, who covers science and writes a science column for the Newark Star-Ledger in New Jersey, the youngest ever to do so. "Reporters have to ask tough questions. We know we aren't always going to be liked," she says.

Make it clear, she urges: "Lots of translations occur and mistakes can happen if your communication to the media is not clear. It may be obvious to you, but those who don't understand something may not know why it's important unless you can explain it."

About biotechnology: "People don't understand it," she says. "It may be a pain in the neck for you to have to explain basic material all the time--but it is necessary," she emphasizes. Be sensitive to the fears of the public, she urges. "Scientists in their work may get out of touch with the public," she suggests. And don't ask to see a newspaper story before it's printed. That's just not done, she says.

MARK CRAWFORD, with Science magazine, deals with scientists regularly. His advice: "Let the data prove your case. Be as forthcoming as possible. Tell your story, but don't oversell it. Spend time with reporters--many publications don't devote the resources to hire science reporters. You have to keep explaining it to new reporters; it's a constant re-education process--and you have the same responsibility with the general public.

"I can't do my job unless you give me the time and play professor," says Crawford. Even though he deals with a sophisticated audience that is interested in science, Crawford advises: "Communicate in simple terms. Be concise."

BIOTECHNOLOGY FOR AGRICULTURE has dealt more in promises than products thus far, says Earl Ainsworth, editor and senior vice president of Farm Journal. "It has gotten to the point where the eyes of farm magazine editors glaze over at the mention of biotechnology," he says. "Farm publications are used to reporting meaningful changes," he stresses.

Farmers are asking about biotechnology: "At what cost to my neighbor? It's as if farmers have split into two groups--those taking the high road of technology, and those taking the low road of alternative agriculture," says Ainsworth, who is national president of the American Agriculture Editors' Association.

"Tell farmers through magazine writers less of how something came about, and more about what it will do for me," he advises, and notes that the secretiveness of commercial companies regarding their work in biotechnology "rivals the CIA. And I can't help but feel that it is excessive."

Farmers are justifiably nervous, Ainsworth observes. "People are better informed and more confused than ever. There is an opportunity here for agricultural biotechnology, but it is off to a fitful start," he says.

BIOTECHNOLOGY IS SO SWEEPING, the techniques so different, the changes so rapid, and the potential so dramatic for everyone, that such a field requires a high degree of continued communication with the public. That communication is a two-way process--from the biotechnology scientists to keep the public informed and from the public to biotech scientists, reminds Sharon Schmickle, Minneapolis Star Tribune. If you don't really listen to the public, you miss opportunities, she reminds biotech scientists.

Her advice to scientists: Be flexible and don't bristle when you get tough questions from the media. That's how reporters get their information and get to the point of public concerns. A tough question gives you an opportunity to straighten out misunderstandings.

THE READING PUBLIC has limited information about science and may be wary of what scientists are doing in their laboratories, says Schmickle. Remember, too, that information about biotechnology is competing with all the other events of the world for the space available in newspapers. Biotech information must be understandable and readable, says Schmickle, who has won several awards for investigative reporting.

Schmickle advises: Don't try to "get a little publicity" or "place a story" with reporters by giving them free products or gadgets. Tell the truth...don't deceive...remember that reporters are allergic to "hard sell." However, if you are good at what you do...if you can use straight everyday talk...and if you are available, you can become a "common source" on biotechnology for the press. She suggests that biotech scientists should identify good solid journalists and get acquainted with them.

FARM PUBLICATION WRITERS want honest straightforward answers. If you can't discuss something, say so...writers will understand...advises Gary Vincent, senior editor of Successful Farming and former editor of Farm Computer News.

After interviewing you, farm magazines are likely to provide you with "checking copies" of draft articles so you can correct any errors, says Vincent, former national president of the American Agricultural Editors' Association. The idea is to have a factual, accurate article, but still written well and interestingly so people will read it. Emphasize what the biotech research or product will do for the farm reader, advises Vincent.

A SURVEY OF SUCCESSFUL FARMING readers shows that they have a positive attitude toward agricultural biotechnology. There is some concern about patenting animals. "Critics of biotechnology aren't going to go away," says Vincent, who specializes in covering biotechnology for Successful Farming. "Try to understand the concerns of your critics and deal with those concerns."

And keep farm magazine writers informed. Pick up the phone and call when you have something of interest. The writer probably will want to know how many others you are calling, or whether you are making a general release of information. "Whatever situation it is, we can deal with it. We just want to know so we can do our planning," says Vincent.

THE PUBLIC IS INTERESTED in how biotechnology is regulated. There is confusion about that. People want to know: "Is it safe?" says Tom Meersman, energy, environmental, and natural resources reporter for Minnesota Public Radio. "Get your biotechnology act together and understand the political realities," says Meersman. The political arena is the public...politics is responsive to the public and its concerns...and the public has many spokespersons, he points out.

People want assurances regarding biotechnology risks--and they want to hear about this from someone, such as a responsible public official, in the State or local area, says Meersman. "Don't expect the public or the press to take everything you say at face value," says Meersman.

Biotechnology is operating in an area where the public is influenced by what has already happened and is happening, not just in biotechnology, but in other areas of science. That can include such things as nuclear power and chemicals. "Expect close scrutiny...challenging questions...and balanced stories from good reporters," says Meersman, who has won numerous media awards, and broadcasts daily on the 12-station Public Radio network in Minnesota and surrounding States.

RADIO AND TV FARM REPORTERS want their material to be listened to, so they are looking for material that is concise, to the point, understandable, and makes some difference to their listeners and viewers, says Orion Samuelson, vice president and agricultural services director of WGN Continental Broadcasting Company in Chicago.

Farm broadcasters can be your window to the public, says Samuelson, who fills 14 daily reports on WGN Radio, 15 daily reports on the Tribune Radio Network serving 45 Midwest stations, is heard daily on 300 radio stations across the country, and produces and hosts a weekly 30-minute TV show seen on 140 stations and 7,000 cable systems served by WGN-TV.

IF A BIOTECHNOLOGY DEPARTMENT in a university or in a biotechnology company deals with the media through an information spokesperson or a public relations representative, be sure they understand what you are doing with biotechnology at the university or in the company, Samuelson advises biotechnology scientists. Broadcasters can get turned off by someone who can't answer their questions in some depth, and with some understanding, says Samuelson, former national president of the National Association of Farm Broadcasters.

THE PUBLIC IS PERPLEXED, Samuelson says. People wonder, for example: Why do research in biotechnology to produce more products when we already have too much? Why are there so many hungry people in the world when we have so much food? And why should taxpayers pay farmers to produce more of what we already have too much of? You may have a ready answer, but the public doesn't.

Further, the public is increasingly concerned about safety, says Samuelson. "Ethical-moral questions about biotechnology are alive in the public; there's a feeling that biotechnology is dealing with creation...and emotional animal rights concerns are out there--and they need to be dealt with. Be truthful ...don't be evasive...and don't get angry," says Samuelson.

THE FUTURE FOR AGRICULTURAL BIOTECHNOLOGY

IT IS GENERALLY AGREED: The public is a full player in establishing the biotech success curve through influencing the flow of funds into research, the rules for testing and releasing biotech materials, and the acceptance of biotech products. Thus the emphasis on "Agricultural Biotechnology and the Public" in the four regional conferences held cooperatively by the U.S. Department of Agriculture, land-grant universities, State Agricultural Experiment Stations, and the Cooperative Extension Services.

"THESE REGIONAL CONFERENCES have helped us update the latest developments in biotechnology...openly discuss controversy...extend the field of understanding ...take a peek into the future...and learn together," says USDA Assistant Secretary for Governmental and Public Affairs Wilmer D. Mizell.

"PUBLIC INVOLVEMENT in the development of biotechnology meets a crucial need if the potential of this industry is to be realized," says Dean Kleinschuster, Rutgers University. We want citizens to be able to make informed decisions, not to react impulsively to scare stories, he comments. "Yet we are hindered by a pervasive scientific illiteracy in this country. Some groups would like to halt biotechnology research until they have had time to gain a better understanding of the issues. With world trade as competitive as it is, that luxury does not exist!" Dean Kleinschuster emphasizes.

"RESEARCH IS A RACE. FIRST PRIZE goes to whoever gets there first to enjoy the benefits," observes Dr. James Halpin, director-at-large, Southern Agricultural Experiment Station Directors.

"HISTORY WILL LOOK BACK at where we are today and will characterize this as the beginning of another major revolution in agriculture that could dwarf the effects and magnitudes of the preceding revolutions," says Dr. Farrell, University of California.

MEANTIME, THOUGH, THERE'S TROUBLE. The biotechnology process is in question. Biotechnology results...particularly bad results...are fantasized. People naturally think of such things as mad scientist movies and "killer bees." People pick up the fear "that if you make something living in the laboratory it will get out of hand and become highly mobile and toxic and nothing will eradicate it except the National Guard," observes Paul Bendix of the Talbott Group.

THAT CALLS US TO EXPLAIN...illuminate...and defend the biotechnology process. "We must educate, investigate, automate, and facilitate biotechnology dreams through enlightened public and private policy," advises Dr. Gerald G. Still, director of USDA's Plant Gene Expression Center, Albany, Calif.

"How well we succeed in each case will directly affect economic vitality, national security, personal happiness and well-being, far into the next century," Dr. Still says.

It will take an educated scientific workforce to discover and advance the technology that has been our country's strongest competitive advantage, says Dr. Still. "Technology superiority can never be taken for granted," he says. "The only long-term assurance of technological superiority is to stay on the leading edge," he adds, and sums up: "At stake is not only our international prestige, but survival--not only our standard of living, but also our national security and the quality of our life."

WE NEED TO START IN KINDERGARTEN through the 12th grade and upgrade the teaching of science and biotechnology, says Ken Farrell. We need to go on from there, he says, to reexamine, renew, and create new ways to "assure effective transfer of technologies from the laboratory to the field." He points to Japan's effectiveness. "The modern curriculum in many of our K-12 American public schools is not a good omen for the future," says Farrell.

THE PUBLIC IS OVERLY INFLUENCED BY SCIENCE FANTASIES, such as they have seen in movies, Paul Talbott, reemphasizes. Many people have a poor understanding of science and what goes on in laboratories, he points out.

Consequently, the public carries mental images of movie tales of scientists creating monsters in their laboratories...or huge insects...or microbes...or man-eating plants...or just plain globs. Inevitably the laboratory creature escapes and creates havoc before being barely subdued, only after heroic efforts; otherwise it wouldn't make a movie.

Thus people are prone to think that something is going to go wrong in science, including biotechnology, says Bendix, who counsels scientific groups.

THOSE CONCERNS HAVE TO BE BALANCED OFF with a wider understanding of the dramatic advances in agricultural biotechnology that are creating opportunities, never before possible--or never even thought of:

For overcoming hunger and disease in the world...
Increasing the nutritional content of foods...
Creating new, more convenient, more flavorful foods...
Making the food supply safer...
Decreasing food and fiber costs...
Improving food preservation to serve needs better around the world...
Improving fibers...
Cutting production costs...
Conquering weeds and insects...
Reducing damage to the food supply...
Creating higher value uses for farm products to improve farm profitability...
Reducing the reliance on chemicals...
Reducing the danger from chemical residues...
Improving the environment...
Reducing and using environmental wastes...
Cleaning up environmental contamination...
Stretching and conserving our energy supplies and scarce natural resources...
Expanding and strengthening renewable resources...
Reducing suffering in livestock from pests and diseases...
Unlocking the benefits of undiscovered genes in plants and animals, on land and sea, that can be shifted to other species for the benefit of all...
Making the U.S. more competitive in international agricultural markets...
Learning from biotechnology discoveries with farm animals how to improve human health...
Creating new pharmaceuticals to treat human diseases, relieve human suffering, and enhance and prolong human life...
And to discover and produce for the benefit of humankind increased bounty from a world we so little understand.

"WITH FULL PARTICIPATION BY THE PUBLIC, farm groups, urban groups, interest groups, information media, and the impetus of the sponsoring groups for the four agricultural biotechnology conferences, we can gather strength from each other...get insight and enlightenment from each other...sharpen our goals and mature our judgment together...and achieve success together in a manner that would honor God and man," says Deputy U.S. Secretary of Agriculture Peter Myers.

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